An Ecosystem Model Comparison on the Northeast U.S. Continental Shelf Using Data Assimilation

Yongjin Xiao, Marjorie A.M. Friedrichs

Virginia Institute of Marine Science, College of William and Mary, Gloucester Point VA, 23062-1346, USA

Summary

Now that large-scale hydrodynamics can be reasonably well reproduced by basin and global scale ocean models, significant effort is being directed toward incorporating complex food webs into these models, which now routinely include multiple phytoplankton (P) and zooplankton (Z) compartments. This naturally leads to the question: how many P and Z compartments should be included in these models in order to accurately simulate coastal carbon cycles? Here we address this question by implementing five ecosystem model variants (Fig. 1) in a 1D assimilative (variational adjoint) model testbed at two sites along the northeastern U.S. continental shelf (Fig. 2), in order to rigorously compare the skill of the model variants. The five models resemble one another except for variations in the level of complexity included in the lower trophic levels, which range from a simple 1P1Z food web to a considerably more complex 3P2Z food web. Numerical twin experiments illustrated that the assimilation of satellite chlorophyll and particulate organic carbon (POC) data resulted in the recovery of multiple parameters for all five models (Fig. 4); however, it was not possible to recover parameters associated with multiple P compartments (e.g. both small P and large P growth rates; Fig. 3). When actual satellite data were assimilated, all five models showed improvements in model-data misfits, yet the magnitudes of improvement varied: the 1P1Z model generated reasonable model-data misfits at individual sites (Fig. 5a, 7), but the parameters optimized for those individual sites produced larger misfits when used at the other site along the U.S. east coast (Fig. 5b, 8). When assimilating data from both sites simultaneously, the 3P1Z model showed the lowest model-data misfits whereas the 2Z models did not show significant improvement compared to the other models (Fig. 6, 8). These preliminary results suggest that incorporating three P groups will be required to accurately simulate the ecosystem on the U.S. eastern continental shelf, whereas a second Z size class may not be required for this particular study region.

1. Methods

1.1. Assimilative framework

- 1D Physical model
- Ecosystem model: 5 variants: 1P1Z ~ 3P2Z
- Parameter optimization method: variational adjoint method

1.2. Numerical twin experiments

- 1st simulation: Run model with **parameter set 1** and subsample the simulation results to obtain a model-generated synthetic data time-series
- 2nd simulation: Run model with altered parameters (**parameter set 2**) and iteratively assimilate the synthetic data to recover parameter set 1

1.3. Assimilating satellite data (Chl+POC)

- **Individual assimilation**: assimilating data at each individual site
- **Simultaneous assimilation**: assimilating data from both site simultaneously
- **Cross validation**: model estimates when applying parameter set obtained from assimilating data at a different site

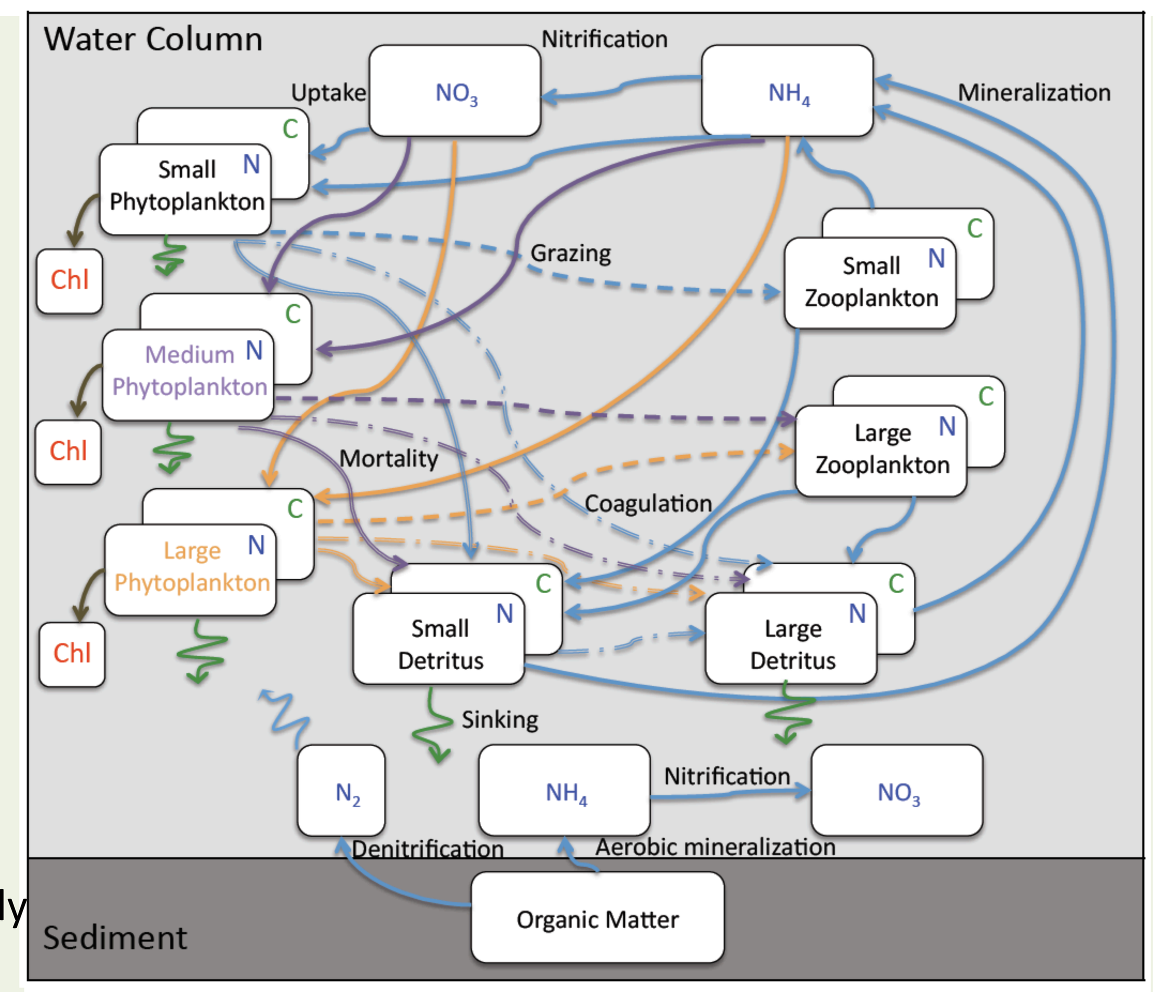

Fig. 1 Ecosystem model conceptual diagram for the 3P2Z model.

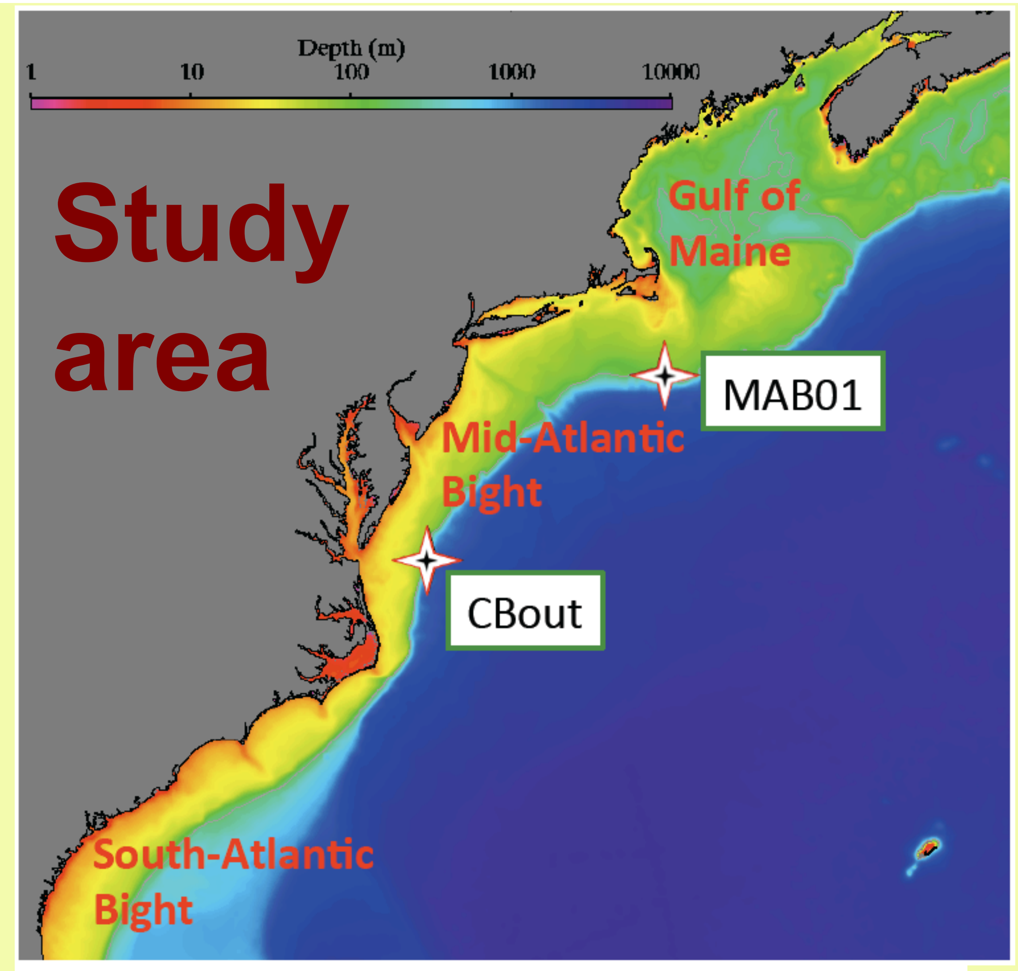

Fig. 2 Study area: U.S. north-eastern continental shelf.

2. Results

2.1. Numerical twin experiments

Twin Exp. 1

- Same model: 2P1Z
- Different parameter sets

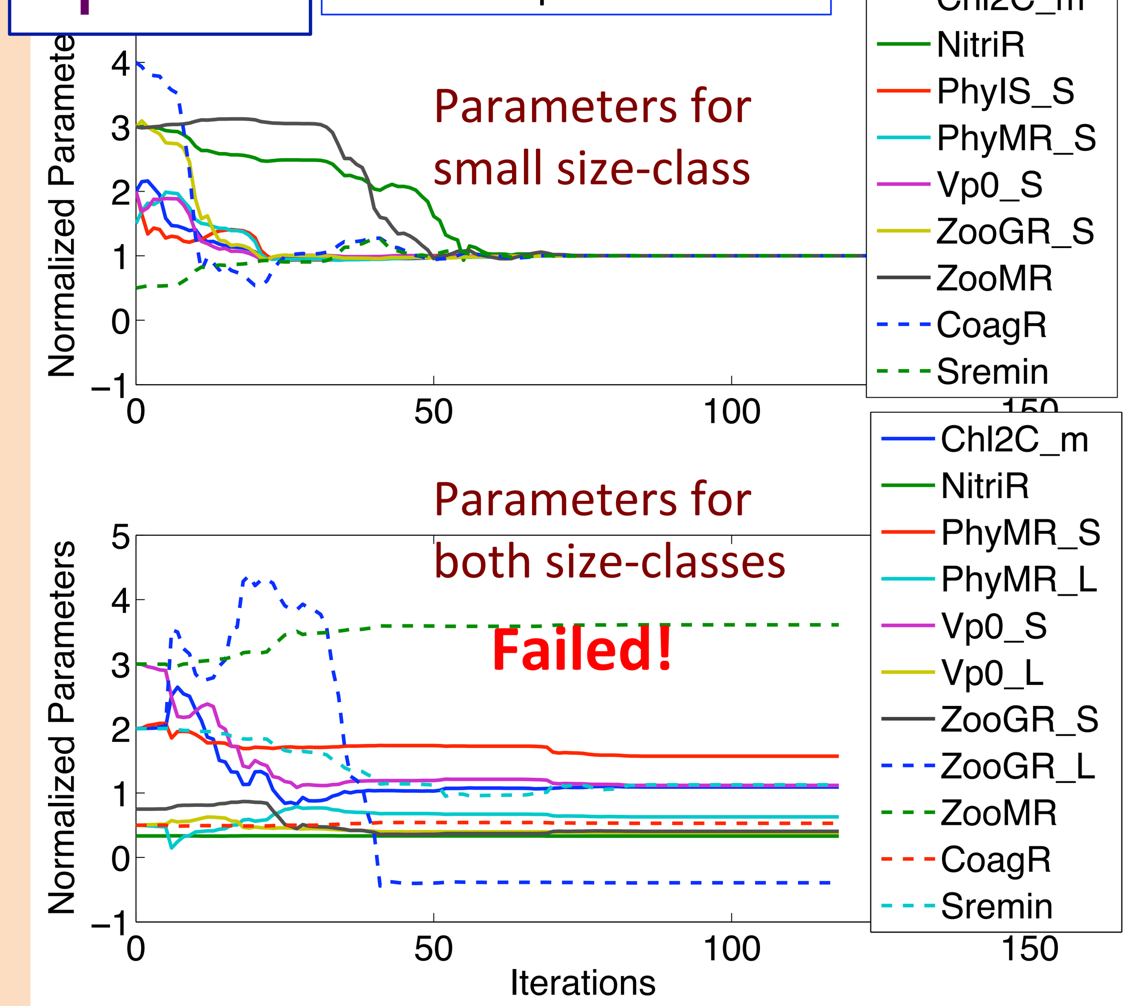

Fig. 3 Recovery of the model parameters for twin exp. 1.

Twin Exp. 2

- Same parameters
- Different models

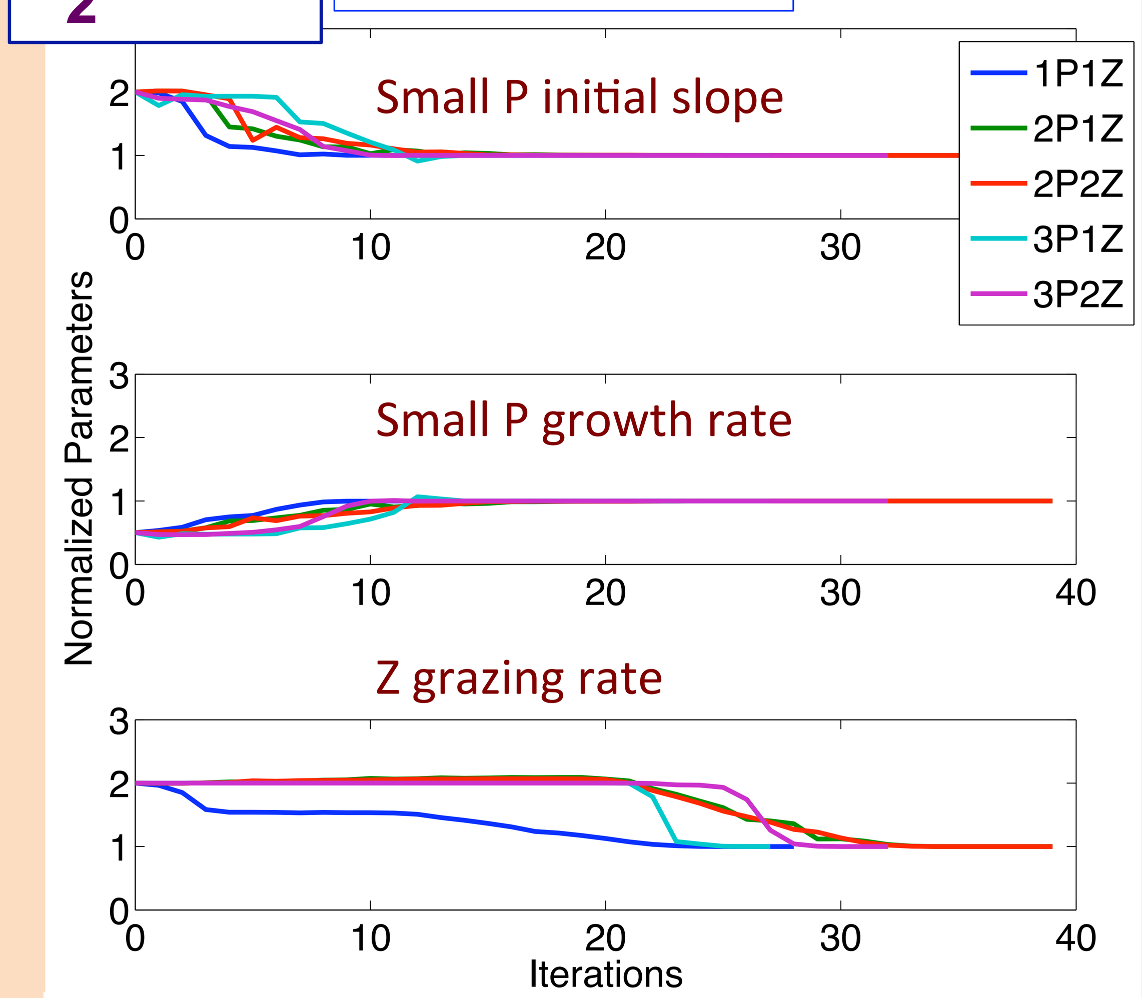

Fig. 4 Recovery of the model parameters for twin exp. 2.

2.2. Assimilating satellite data

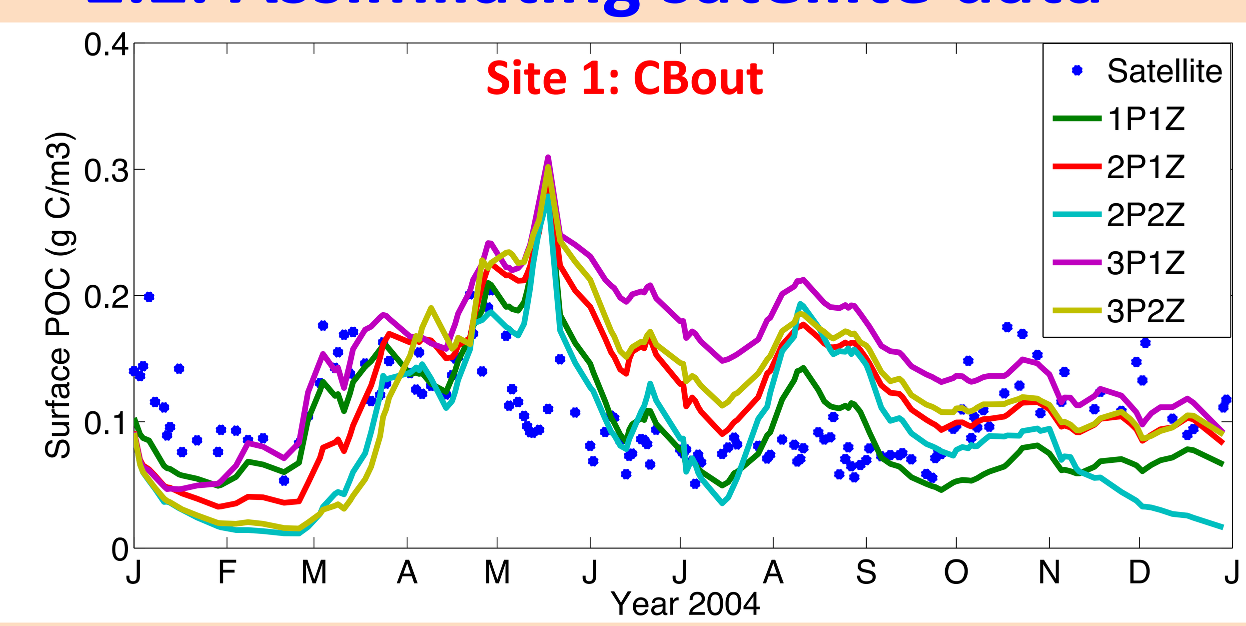

Fig. 5a Individual assimilation at CBout site.

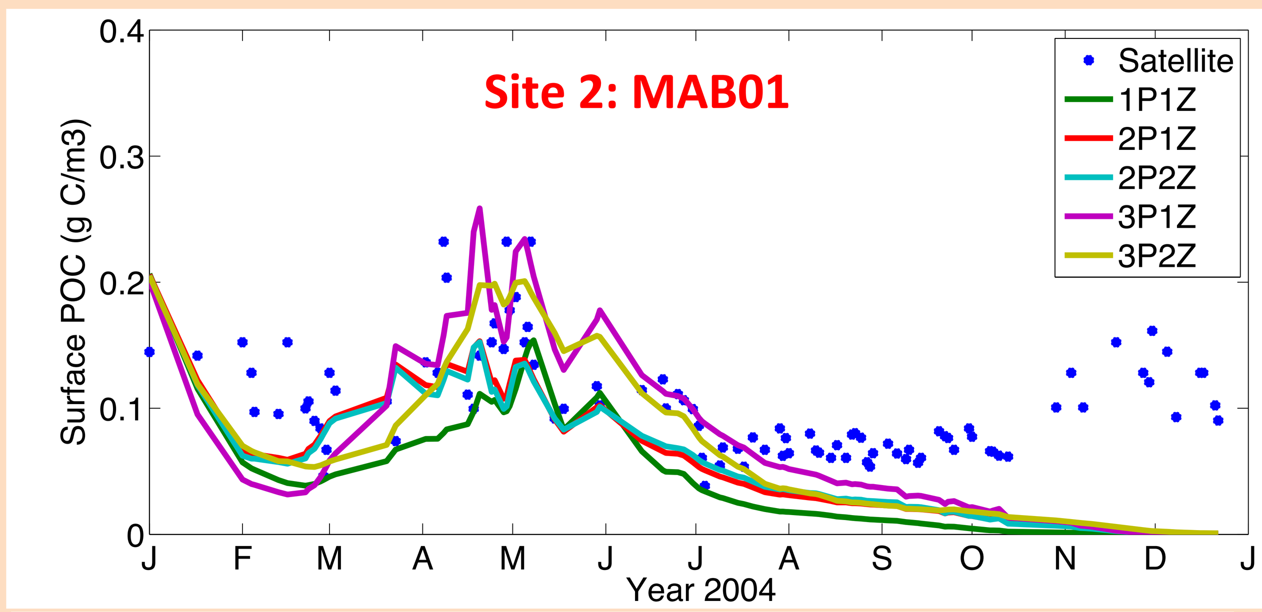

Fig. 5b Cross validation showing surface Chl and POC estimates at MAB01 when applying parameters from individual assimilation at CBout.

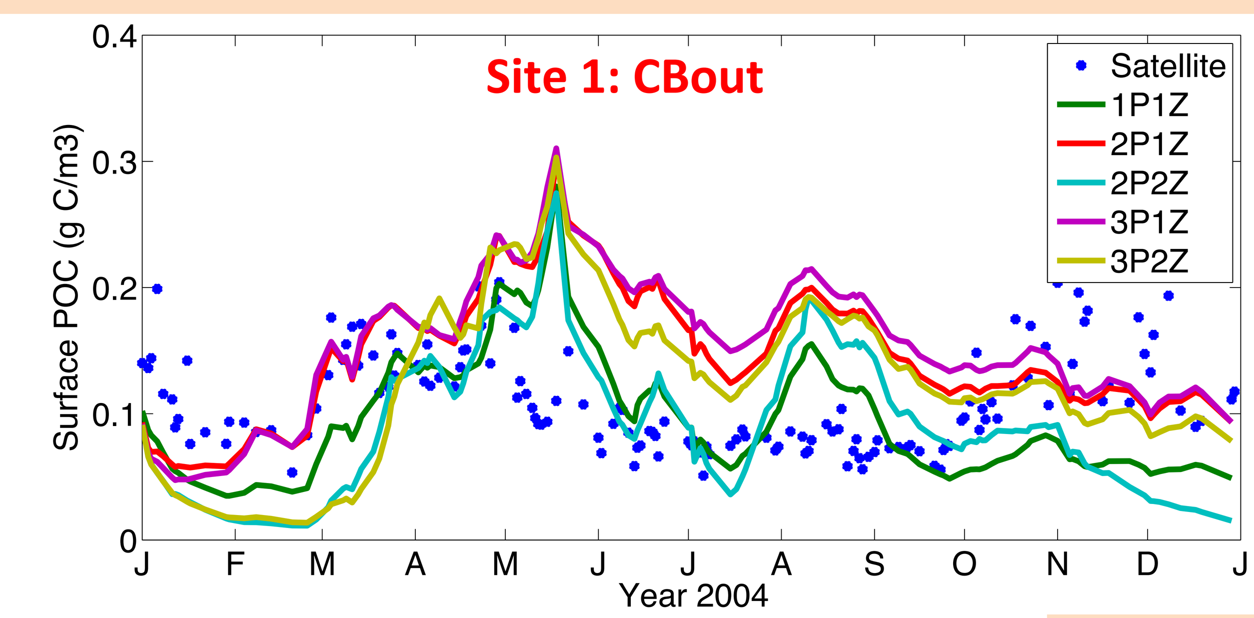

Fig. 6a Simultaneous assimilation at CBout.

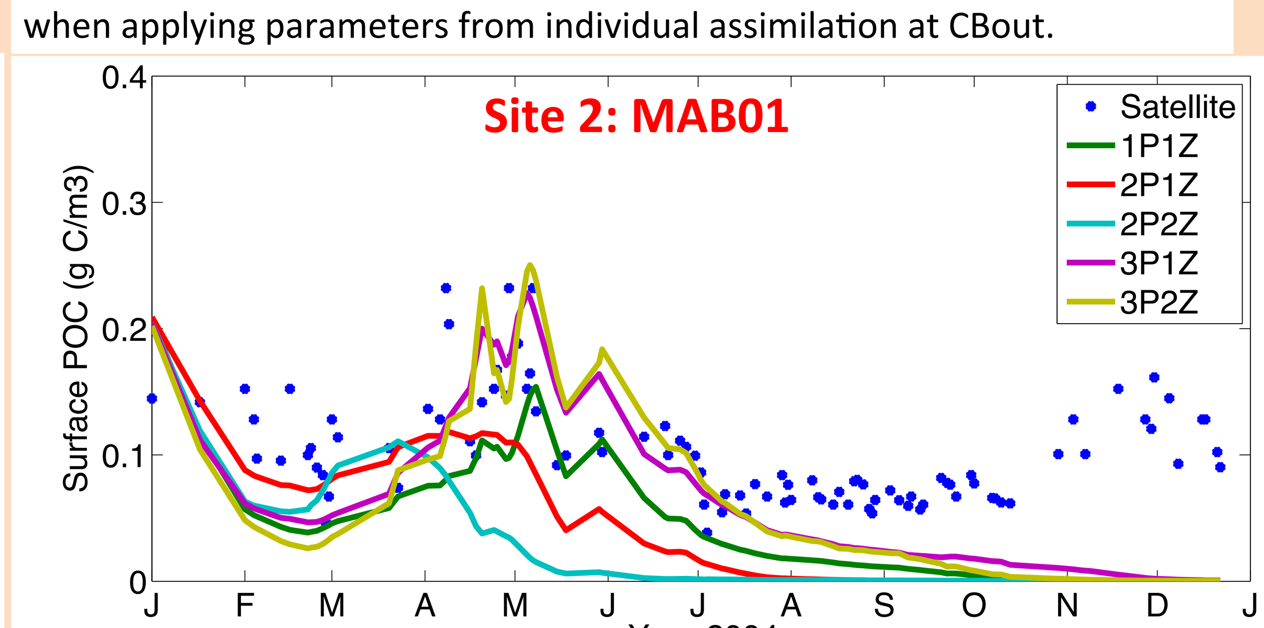

Fig. 6b Simultaneous assimilation at MAB01.

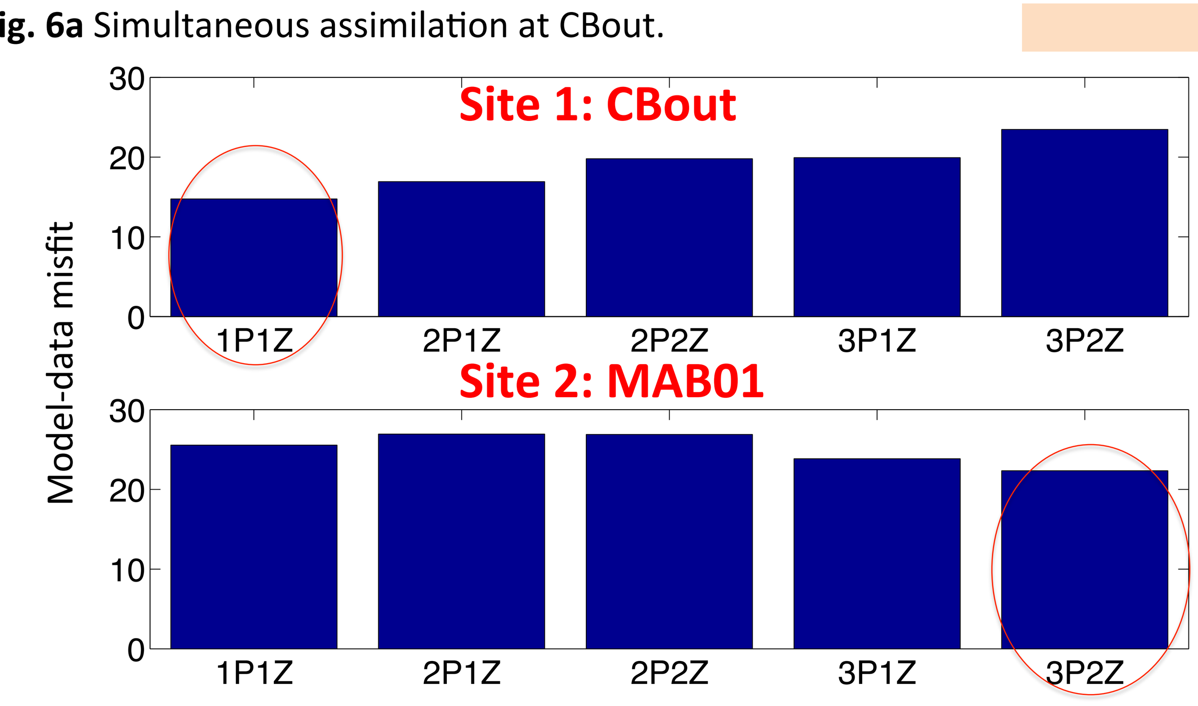

Fig. 7 Model-data misfit for individual assimilation.

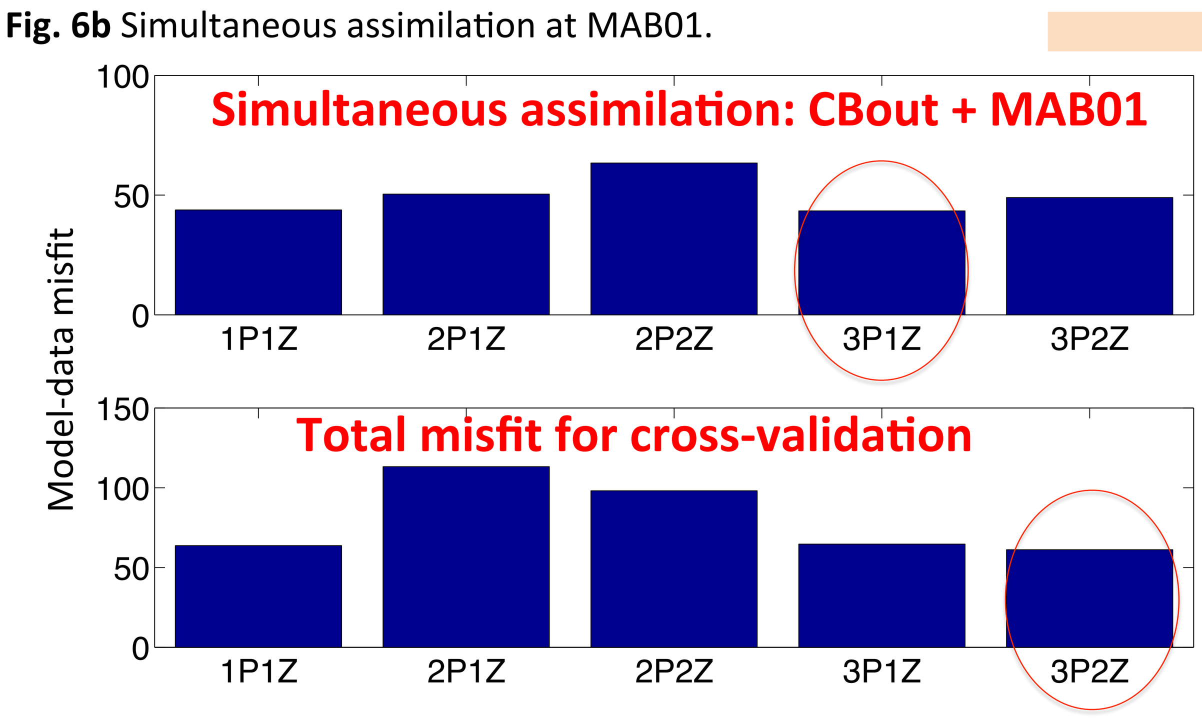

Fig. 8 Total model-data misfit after simultaneous assimilation from both site and total misfit for cross-validation.

3. Conclusions

- Twin experiments showed that variational adjoint method can successfully recover parameters but cannot optimize parameters associated with multiple P compartments.
- At individual sites, the simplest model does as well as the complicated models after optimization, however, the more complex models do best for simultaneous assimilation and the cross-validation.

Acknowledgments: The project is supported by the NASA NESSF fellowship, and the authors would like to thank NASA USECoS group for their helpful comments.